USAARL Report No. 98-26

Effects of Seat Stroke Distance on the Allowable Mass of Head Supported Devices
~~(Reprint)~~

By

Amir A. Mobasher
Frederick T. Brozoski

UES, Inc.

and

B. Joseph McEntire
Nabih M. Alem

Aircrew Protection Division

April 1998

U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:

John P. Albano

JOHN P. ALBANO
MAJ, MC, SFS
Director, Aircrew Protection Division

John A. Caldwell, Ph.D.

JOHN A. CALDWELL, Ph.D.
Chairman, Scientific Review Committee

Released for publication:

Cherry Gaffney

CHERRY L. GAFFNEY
Colonel, MC, SFS
Commanding

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release, distribution unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 98-26	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory 6b. OFFICE SYMBOL (If applicable) MCMR-UAD	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research and Materiel Command
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 620577 Fort Rucker, AL 36362-0577	7b. ADDRESS (City, State, and ZIP Code) 504 Scott Street Fort Detrick MD 21702-5012
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
62787A	30162787A878	EA	DA302870

11. TITLE (Include Security Classification)
Effects of seat stroke distance on the allowable mass of head supported devices (Reprint) (U)

12. PERSONAL AUTHOR(S)
Amir A. Mobasher, Frederick T. Brozoski, B. Joseph McEntire, and Nabih M. Alem

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM TO	1998 April	13

16. SUPPLEMENTAL NOTATION
Originally published in proceedings of "The Design and Integration of Helmet Systems" Symposium, held in Framingham, MA, 2-5 December 1997

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
head-neck interface, head supported devices, articulated total body, seat stroke, simulations, helicopter crashes

19. ABSTRACT (Continue on reverse if necessary and identify by block number)
The effects of stroking distance of energy-attenuating helicopter seat on head-supported device (HSD) masses were investigated in various helicopter crash scenarios. The articulated total body (ATB) model was used to simulate the helicopter pilot's biodynamic response to five different crash pulses. Parameters of the simulations included two allowable seat stroking distances (2.5 and 25 cm) and four HSD masses (0.45, 1.4, 2.7, and 4.1 kg). The simulations were performed with the mid-sized Hybrid III manikin as the occupant model, and the HSD center of mass (CM) coincident with the CM of the Hybrid III head. Moments and forces produced by the ATB simulations at the head-neck interface (occipital condyles) were assessed against injury thresholds to determine the risk of neck injury. Acceptable head-supported masses were established then for the given impact conditions. The report concludes that acceptable HSD mass was highly dependant on seat stroke distance and impact conditions, which include crash pulse magnitude, direction and shape. For a Hybrid III dummy, increased available seat strokes resulted in lower loads transmitted to the head-neck interface, thereby allowing larger HSD masses to be worn.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Science Support Center	22b. TELEPHONE (Include Area Code) (334) 255-6907 22c. OFFICE SYMBOL MCMR-UAX-SI

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

EFFECTS OF SEAT STROKE DISTANCE ON THE ALLOWABLE MASS OF HEAD SUPPORTED DEVICES

Amir A. Mobasher*
Frederick T. Brozoski*
B. Joseph McEntire**
Nabih M. Alem**
*UES, Inc.
4401 Dayton-Xenia Road, Dayton, OH 45432-1894 USA

**U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama 36362-0577 USA

Abstract

The effects of stroking distance of energy-attenuating helicopter seat on head-supported device (HSD) masses were investigated in various helicopter crash scenarios. The articulated total body (ATB) model was used to simulate the helicopter pilot's biodynamic response to five different crash pulses. Parameters of the simulations included two allowable seat stroking distances (2.5 and 25 cm) and four HSD masses (0.45, 1.4, 2.7, and 4.1 kg). The simulations were performed with the mid-sized Hybrid III manikin as the occupant model, and the HSD center of mass (CM) coincident with the CM of the Hybrid III head. Moments and forces produced by the ATB simulations at the head-neck interface (occipital condyles) were assessed against injury thresholds to determine the risk of neck injury. Acceptable head-supported masses were established then for the given impact conditions. The report concludes that acceptable HSD mass was highly dependant on seat stroke distance and impact conditions, which include crash pulse magnitude, direction and shape. For a Hybrid III dummy, increased available seat strokes resulted in lower loads transmitted to the head-neck interface, thereby allowing larger HSD masses to be worn.

Introduction

Aircraft crew safety and crash survival have been the subject of considerable attention since the early days of aviation. In the evolution process of Army aircraft, numerous protective devices and systems have been introduced into the aircraft/aircrew. Some of these devices include helmet-mounted electronics, protective masks, body armor, advanced restraint systems, inflatable restraint devices and energy attenuating seats. Of the additional equipment carried by an Army aviator, few serve as many functions as the modern helmet. In addition to providing head impact protection, today's helmet is a mounting platform for many advanced devices such as night vision goggles (NVG) and integrated helmet and display sighting system (IHADSS).

Paper presented at "The Design and Integration of Helmet Systems" Symposium, Framingham, MA, 2-5 Dec 97, Sponsored by U.S. Army Natick Research, Development and Engineering Center, Soldier Systems Command, Natick, MA; The Defence Evaluation and Research Agency, Farnborough, U.K.; and the National Defense Industrial Association (NDIA), and published in the Proceedings.

The addition of HSDs has increased the risk of neck injury due to inertial loads generated during helicopter crashes. Furthermore, it is hypothesized that the use of energy attenuating helicopter seats may influence helmet design. Therefore, the objective of this study is to investigate the effects of stroking distances on the inertial loads being exerted on the head and neck in five typical helicopter crash environments and four different HSD masses.

Biodynamic simulations

A widely used tool for accident reconstruction is the ATB simulation software (references 2 and 6). Given a number of body segments connected by mathematical models at common joints, the ATB automatically formulates the differential equations that govern the motion of the body segments. The model is driven by acceleration pulses which approximate the crash profiles. The ATB then integrates those equations to compute the kinematics of every body segment and to calculate the forces at all joints. The software can be requested to produce time histories of forces and accelerations of body segments which are used to predict injuries.

A number of parameters were considered to determine head-borne mass criteria under various conditions. Using ATB simulations, biodynamic response to five different crash pulses, also referred to as impact conditions, were generated for the Hybrid III manikin. The GEBODIII program (references 3 and 4) was used to generate the segment and joint data for a sitting Hybrid III dummy. For each of these five impact conditions, four different HSD masses and two different seat stroke distances were considered. Time histories for the transmitted head and neck forces and moments were recorded for each case. These time histories were used to determine a correlation between the HSD mass and transmitted force or moment levels for each allowable seat stroke distance. The following parameters were modeled in the simulations:

Impact conditions. The five impact conditions detailed in Figure 1 were considered. The first condition was a 25 g vertical triangular pulse of 128 millisecond (msec) duration (velocity change of 15.7 $m \cdot sec^{-1}$) with 30° pitch and 10° roll subject orientation. The second condition was a 30 g horizontal triangular pulse of 160 msec duration (velocity change of 23.5 $m \cdot sec^{-1}$) with 30° yaw subject orientation. The third condition was an 18 g vertical triangular pulse of 148 msec duration (velocity change of 13.1 $m \cdot sec^{-1}$) with 30° roll subject orientation. The fourth pulse was a 10-48 g vertical bi-level pulse of 110 msec total duration (velocity change of 18 $m \cdot sec^{-1}$) with 30° pitch and 10° roll subject orientation. Finally, the fifth condition was a 30 g horizontal trapezoidal pulse of 70 msec duration (velocity change of 15.5 $m \cdot sec^{-1}$) with 30° yaw subject orientation.

Helmet mass. Four HSD masses of 0.45, 1.36, 2.72, and 4.09 kilograms were simulated. The effect of helmet mass was incorporated into the head segment by adding the mass of the helmet to the mass of the head. Then, the mass moments of inertia of the head segment were altered to account for the additional mass.

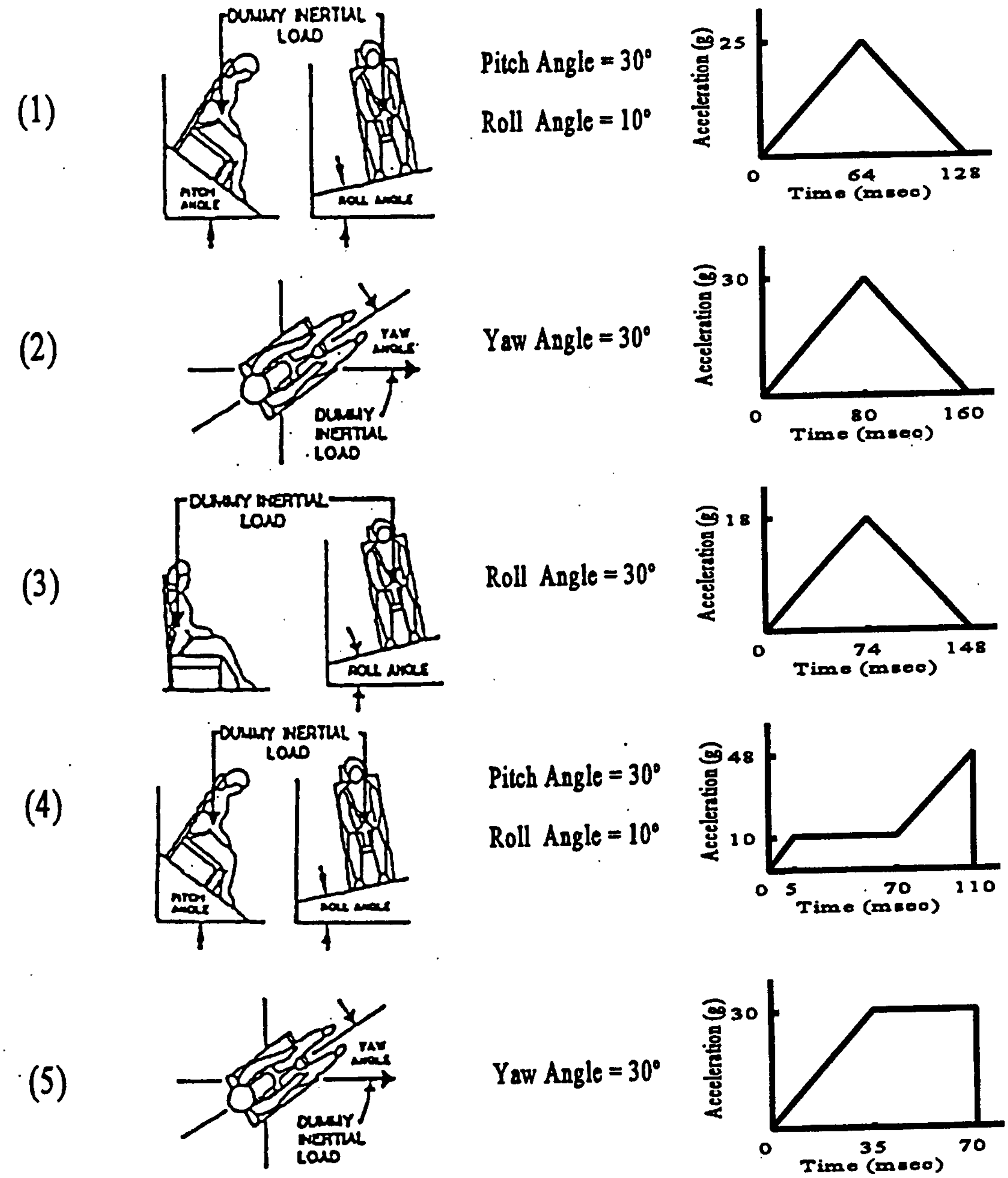


Figure 1. Description of the five impact conditions applied to the floor of the helicopter.

CM location. One CM position was simulated in this study. The CM of the HSD mass coincided with the CM of the head. For the Hybrid III dummy, this location is 1.4 centimeters (cm) above and 5.08 cm to the front of the occipital condyles in the mid-sagittal plane.

Seat stroke. The effect of seat stroke was incorporated into the simulations (reference 1). Since the UH-60 and AH-64 helicopters are equipped with energy absorbing seats, the simulations were expanded to include the stroking of the seat. These simulations were confined to allowable seat stroke distances of 2.5 cm and 25 cm.

Restraint system. A standard four-point restraint system was used in the simulations. The harness system was modeled to simulate "no malfunctions" during the different crash scenarios, i.e., the inertia reels locked at the onset of each crash pulse.

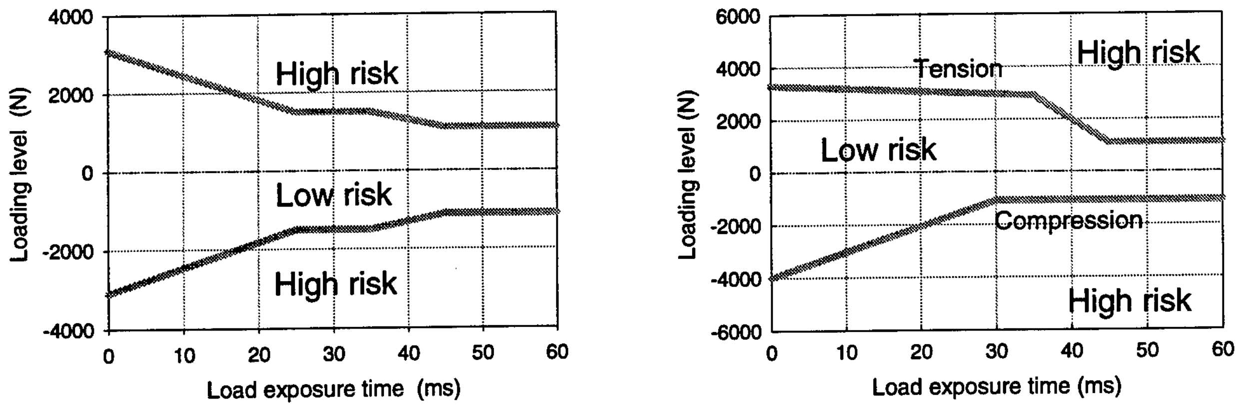
Complete motion. The total duration of each simulation was confined to 400 msec. This was necessary to allow sufficient time for the head motion to develop. Response parameters were output at 1-msec intervals.

Inertial loading. Only the inertial loading exerted on the head-neck interface was considered. This was accomplished by determining the point in time, if any, at which the head contacted the seat's headrest. The analysis process was then carried out to that time point only. Beyond that point, the data was determined to be contaminated by contact forces and, therefore, not representative of purely inertial loadings.

Injury assessment

Injury assessment generally requires the use of crash dummies in actual crash tests to determine the forces of impact. These forces are then used to assess the risk of injury to humans. The method of assessment is to compare the magnitudes and durations of individual force and acceleration pulses, measured at strategic locations in the dummy, to acceptable tolerance limits. Assessment methods and injury criteria are well defined for the Hybrid III type dummies (reference 5). In this study, the same assessment methods and injury criteria are applied to the time history generated by the ATB simulations. The main features of the analysis method used in this study to arrive at the injury assessment are explained in the following paragraphs:

Response parameters. Only the response parameters with published threshold values were considered in this analysis. These response parameters were the fore-aft shear forces (±Fx), compression (−Fz), tension (+Fz), extension (−My) and flexion (+My), measured at the occipital condyles. For the extension and flexion moments, the threshold values are constant at 57 N·m and 190 N·m, respectively. The published threshold values for fore-aft shear and compression-tension forces are shown in Figures 2a and 2b, respectively (reference 5).



(a) (b)

Figure 2. Injury threshold curves for (a) fore-aft shear and (b) compression-tension force. Source: Mertz, 1993.

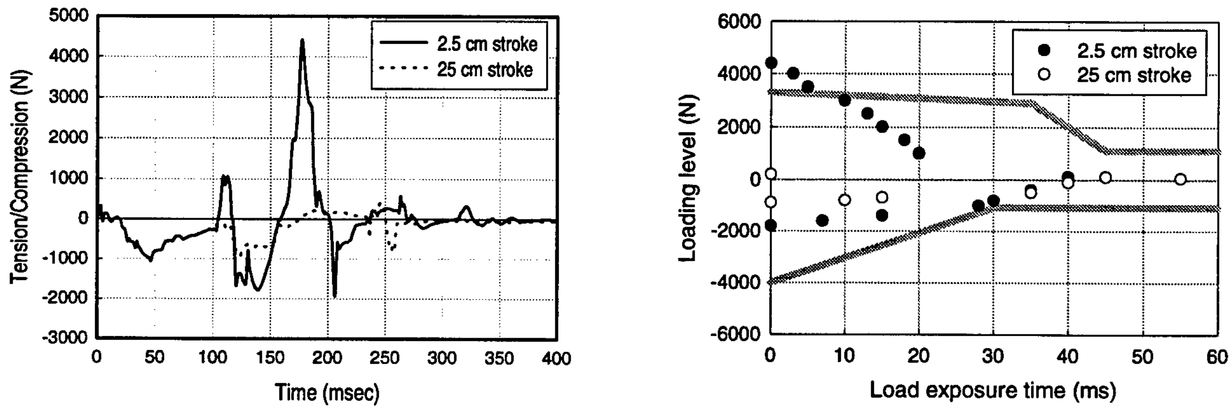
Establishing load duration plots (LDP). In this method, the exposure time, Δt, at which a subject experiences a given level of force or moment was drawn from the time history data. Then, the values of Δt were plotted versus their respective force or moment level. These values were compared to established injury corridors. If any of the response parameter levels crossed the threshold region, the injury risk for that case was assessed as "high." Conversely, if all the levels stayed within the injury corridors, the injury risk for that response parameter was assessed as "low."

Normalized peak values (NPV). A second set of analyses based on the peak values of each response parameter was used to establish limits on the HSD mass. In this analysis method, peak values for each of the six response parameters were extracted from their respective time histories. For each response parameter, the peaks were normalized with respect to threshold values corresponding to an exposure time of 0 msec. Correlations between the HSD mass and these normalized peak values, referred to in this study as NPV, were obtained for each response parameter, impact condition, and seat stroke.

Results and discussions

Time history traces for the six response parameters were output from the simulations. From these time histories, evaluation of the effects of seat stroke was done using the injury assessment techniques described earlier. It should be noted that this assessment method is used as a comparative tool to allow evaluation of results of paired simulations without inferring any injury outcome.

The time history for neck compression-tension force is shown in Figure 3a. In this case, the occupant (Hybrid III) is wearing a 1.4 kg helmet while subjected to impact condition four. In this example, the time history for the allowable 2.5 cm seat stroke distance is represented by the solid line. The results of the allowable 25 cm seat stroke are represented by the dotted line. From this figure it is evident that the peak values of the neck compression and tension forces reduce dramatically for the 25 cm seat stroke as compared to the 2.5 cm seat stroke. The corresponding load duration plots for these two response parameters are shown in Figure 3b. Various loading levels for the 2.5 cm seat stroke are represented by solid bullets. Hollow bullets represent the loading levels for the 25 cm seat stroke. Examination of this figure reveals that increased seat stroke reduces the injury risk by placing the load exposures within the injury corridors.



(a) (b)

Figure 3. Comparison of neck tension-compression between both the 2.5 cm and 25 cm seat stroking distances for the 1.4 kg helmet and impact condition four. (a) Time history, (b) Load duration plots.

The time histories of the six response parameters resulting from all the simulations were analyzed using the same method as depicted above. The results of these analyzations are presented in Table 1 for each combination of HSD mass and impact condition. For comparison, the results of the simulations incorporating 2.5 cm and 25 cm seat stroking distances are paired together. Each entry in the table represents the number of response parameters (out of the six considered) which failed the time history analysis. A failure results when at least one of the data points within the LDP falls directly on or outside of the injury corridor boundaries. If one out of the six response parameters fails the time history analysis, no recommendation on allowable HSD mass can be made.

Consider Table 1 and the first impact condition. For this case, the effect of seat stroking is clearly evident. For an allowable 2.5 cm seat stroke, analysis shows that a high risk of injury is incurred when a 1.4 kg HSD is simulated. Thus, for this combination of impact condition and seat stroke distance, an HSD mass of no greater than 0.45 kg can be chosen. However, for an allowable seat stroke distance of 25 cm, a HSD mass of no greater than 1.4 kg can be selected.

Table 1.
Summary of response parameters which failed the injury test for the two stroking distance and the four helmet masses.

	HSD mass (kg)	0.0		0.45		1.4		2.7		4.1	
	Allowed stroking distance (cm)	2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0	0	0	0	1	0	1	1	3	1
	2	0	0	0	0	2	2	2	2	2	2
	3	0	0	0	0	0	0	0	0	0	0
	4	1	0	2	0	3	0	4	0	5	1
	5	1	1	1	1	2	2	2	2	2	2

Now, consider impact condition four. For the allowable 2.5 cm seat stroke, time history analysis shows that a risk of injury exists even for the lowest HSD masses. Therefore, no safe HSD mass can be predicted. However, for the allowable 25 cm seat stroke, low risks of injury exist up to an HSD masses of 2.7 kg. It must be noted that both impact conditions one and four are dominated by the vertical components of acceleration.

In impact conditions two and five, the stroking of the seat has no pronounced effect on the allowable HSD mass. These two conditions are principally longitudinal with 30° yaw. For these two impact conditions, the number of response parameters which fail the time history analysis is identical for each seat stroking distance. This is due to the fact that the seat stroking mechanism is designed to attenuate energy in the vertical direction only. However, some seats do exist which stroke in the horizontal direction. These seats were not considered in these simulations.

As in impact conditions one and four, impact condition three is also dominated by the vertical components of acceleration (Figure 1). However, no difference is observed in the injury assessments made on the results of both the allowable 2.5 cm and 25 cm seat strokes (Table 1). Due to the nature of this impact condition, sufficient energy was not applied to cause the seat to stroke.

The second set of analysis involves determination of HSD mass based on the peak values of time histories. Tables 2 through 7 list the NPV for each of the six response parameters. Within each table, the NPV are shown for the five impact conditions and all simulated HSD masses. To determine the limit on HSD mass, the mass at which the response parameter intersects the threshold line (NPV equal to 1.0) is found using linear interpolation.

Consider, for example, impact condition one with an allowable 2.5 cm seat stroke. For this case, the peaks for fore-aft shear and tension fall below their respective thresholds for all four HSD masses. For compression, the peak coincides with its threshold at an HSD mass of 2.8 kg (interpolated). For the extension moment, the peak reaches the threshold at 1.15 kg and for the flexion moment, the peak reaches the threshold at 3.1 kg. The limit on HSD mass for impact condition one with an allowable 2.5 cm seat stroke is, therefore, 1.15 kg. That is, the minimum of 4.1 kg, 2.7 kg, 1.15 kg, and 3.1 kg. Using a similar approach, the limit on HSD mass for impact condition one with an allowable 25 cm seat stroke is calculated to be 2.57 kg. Table 8 summarizes the allowable HSD masses for each impact condition and seat stroke distance. As in the time history analysis, it is evident that for impact conditions of primarily vertical nature, higher HSD masses could be accommodated using a 25 cm seat stroke rather than a 2.5 cm seat stroke.

The relationship between HSD mass and normalized peak compression is shown graphically in Figure 4 for impact condition one. From this figure, it is evident that all the peak values obtained for the allowable 25 cm seat stroke fall consistently below the peaks resulting from the allowable 2.5 cm seat stroke.

In all these discussions, keep in mind that only the 50th percentile male aviator was simulated. Results will be different for other aviator sizes, particularly for a small size female. It should also be stressed that these results are based a HSD CM coincident with the CM of the Hybrid III head. These results should not be interpreted to account for CM locations other than the one simulated.

Table 2.
Ratio of peak to threshold of forward shear force for the five impact conditions, two stroking distances and the four helmet masses.

	HSD mass (kg)	0.0		0.45		1.4		2.7		4.1	
	Allowed stroking distance (cm)	2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0.39	0.26	0.45	0.30	0.53	0.36	0.66	0.46	0.75	0.55
	2	0.53	0.53	0.58	0.58	0.65	0.65	0.76	0.76	0.84	0.84
	3	0.17	0.17	0.18	0.18	0.22	0.22	0.27	0.27	0.33	0.33
	4	0.59	0.26	0.64	0.30	0.80	0.38	1.01	0.49	1.20	0.61
	5	0.60	0.60	0.66	0.66	0.74	0.74	0.84	0.84	0.90	0.90

Table 3.
Ratio of peak to threshold of aft shear force for the five impact conditions, two stroking distances and the four helmet masses.

HSD mass (kg)		0.0		0.45		1.4		2.7		4.1	
Allowed stroking distance (cm)		2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0.12	0.07	0.14	0.07	0.17	0.07	0.18	0.07	0.19	0.07
	2	0.06	0.06	0.06	0.06	0.11	0.11	0.10	0.10	0.15	0.15
	3	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
	4	0.25	0.05	0.26	0.05	0.27	0.06	0.18	0.08	0.21	0.07
	5	0.13	0.13	0.13	0.13	0.16	0.16	0.21	0.21	0.16	0.16

Table 4.
Ratio of peak to threshold of compression force for the five impact conditions, two stroking distances and the four helmet masses.

HSD mass (kg)		0.0		0.45		1.4		2.7		4.1	
Allowed stroking distance (cm)		2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0.43	0.28	0.45	0.31	0.62	0.46	0.98	0.78	1.29	0.90
	2	0.26	0.26	0.46	0.46	1.06	1.06	1.06	1.06	1.52	1.52
	3	0.20	0.20	0.22	0.22	0.26	0.26	0.32	0.32	0.38	0.38
	4	0.66	0.26	0.54	0.28	0.59	0.32	0.91	0.51	1.10	0.90
	5	0.24	0.24	0.27	0.27	0.30	0.30	0.36	0.36	0.36	0.36

Table 5.
Ratio of peak to threshold of tension force for the five impact conditions, two stroking distances and the four helmet masses.

HSD mass (kg)		0.0		0.45		1.4		2.7		4.1	
Allowed stroking distance (cm)		2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0.27	0.06	0.32	0.07	0.44	0.08	0.61	0.15	0.75	0.23
	2	0.32	0.32	0.37	0.37	0.49	0.49	0.65	0.65	0.84	0.84
	3	0.17	0.17	0.17	0.17	0.21	0.21	0.28	0.28	0.34	0.34
	4	0.88	0.07	0.98	0.07	1.10	0.11	1.16	0.10	1.49	0.18
	5	0.37	0.37	0.44	0.44	0.55	0.55	0.55	0.55	0.68	0.68

Table 6.
Ratio of peak to threshold of extension moment for the five impact conditions, two stroking distances and the four helmet masses.

HSD mass (kg)		0.0		0.45		1.4		2.7		4.1	
Allowed stroking distance (cm)		2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0.63	0.33	0.70	0.39	1.11	0.81	1.68	1.02	2.42	1.11
	2	0.51	0.51	0.65	0.65	1.09	1.09	1.68	1.68	2.33	2.33
	3	0.49	0.49	0.53	0.53	0.60	0.60	0.81	0.81	0.96	0.96
	4	1.91	0.26	1.81	0.30	2.54	0.47	2.91	0.96	2.58	1.23
	5	1.37	1.37	1.49	1.49	1.75	1.75	2.18	2.18	2.58	2.58

Table 7.
Ratio of peak to threshold of flexion moment for the five impact conditions, two stroking distances and the four helmet masses.

HSD mass (kg)		0.0		0.45		1.4		2.7		4.1	
Allowed stroking distance (cm)		2.5	25	2.5	25	2.5	25	2.5	25	2.5	25
Impact condition	1	0.61	0.31	0.64	0.35	0.77	0.45	0.96	0.57	1.11	0.72
	2	0.47	0.47	0.50	0.50	0.61	0.61	0.75	0.75	0.87	0.87
	3	0.18	0.18	0.19	0.19	0.21	0.21	0.27	0.27	0.36	0.36
	4	0.99	0.34	1.04	0.37	1.34	0.47	1.63	0.60	1.34	0.77
	5	0.77	0.77	0.82	0.82	1.03	1.03	1.25	1.25	1.43	1.43

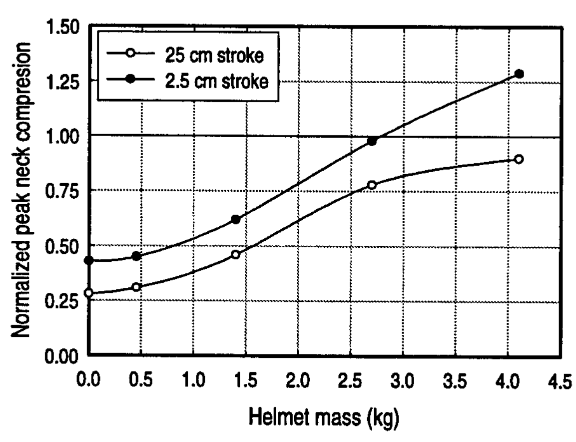


Figure 4. Comparison of normalized peak neck compression as a function of HSD mass between the 2.5 cm and 25 cm seat stroking distances for impact condition one.

Table 8.
Comparison of HSD mass limits for the 2.5 cm and 25 cm seat stroking distances for each impact condition

		HSD mass limit (kg)	
Allowed stroking distance (cm)		2.5	25
Impact condition	1	1.15†	2.57†
	2	0.64†	0.64†
	3	4.10†	4.10†
	4	--*	2.91†
	5	--*	--*

† Extension moment was the governing factor in determining HSD mass limit.
* No limit on HSD mass can be determined. For all simulated HSD masses, at least one response parameter exceeded its threshold.

Conclusions

In this study we examine the effect of seat stroking distance on reducing the severity of potential neck injury to the aircrew during a helicopter crash. For this purpose, we performed mathematical simulations of the pilot's biodynamics to examine the inertial loads at the head-neck interface. The simulations demonstrated that for impact conditions of primarily vertical nature, the peak magnitudes of neck loads were reduced significantly for a 25 cm seat stroke as compared with 2.5 cm seat stroke. This allowed higher HSD mass to be worn. In addition, the primary factor in determining HSD mass limits was the extension moment for both allowable seat stroke distances. No significant differences were observed for impact conditions which were not primarily vertical in nature.

Acknowledgments

The authors wish to acknowledge the U.S. Army Aviation Troop Command (ATCOM), Program Manager-Aircrew Integrated System (PM-ACIS), Air Warrior program, for providing the funding which made this study possible.

References

1. Beale, David, Alem, Nabih M., and Butler, Barclay P., "A correlative investigation of simulated occupant motion and accident report in a helicopter crash," Aviation, Space, and Environmental Medicine, Col. 67, No. 1. January 1996.

2. Fleck, J.T., Butler, F.E., and Vogel, S.L., "An improved three-dimensional computer simulation of crash victims," Washington, DC: Department of Transportation, NHTSA, 1975, Report No. DOT-HS-801-507 through 510.

3. Gross, Mary E., "The GebodIII program user's guide and description," AL-TR-1991-0102, March 1991.

4. Kaleps, Ints, White, Richard P., Jr., Beecher, Robert M., Whitestone, Jennifer, and Obergefell, Louise A. 1988. Measurement of Hybrid III dummy properties and analytical simulation data base development. AAMRL-TR-88-005, February.

5. Mertz, H.J. 1993. Anthropomorphic test devices. Accidental injury: Biomechanics and prevention, Nahum, A.M., and Melvin, J.M., eds. New York, NY: Springer-Verlag.

6. Obergefell, L.A., Fleck, J.T., Kaleps, I., and Gardner, T.R., 1988. Articulated total body model enhancements. Wright-Patterson Air Force Base, OH: Harry G. Armstrong Aerospace Medical Research Laboratory. AAMRL -TR-88-009.

Biographies

Amir A. Mobasher, UES, Inc., c/o USAARL, P.O. Box 620577, Fort Rucker, AL 36362-0577; Telephone (334) 255-6885; Fax 255-7798. Dr. Mobasher is a Mechanical Engineer working for Universal Energy Systems, Inc., in support of the U.S. Army Aeromedical Research Laboratory. He holds a Ph.D. in Mechanical Engineering from University of Alabama in Huntsville. He has ten years of experience in numerical modeling, primarily in computational fluid dynamics and biomechanics. During the past two years, his research has been focused on head-supported mass and center of mass placement in support of U.S. Army aviation.

Frederick T. Brozoski, UES, Inc., c/o USAARL, P.O. Box 620577, Fort Rucker, AL 36362-0577; Telephone (334) 255-6885; Fax (334) 255-7798. Mr. Brozoski is a research engineer working for Universal Energy Systems, Inc. at Fort Rucker, Alabama. He holds a BS in Aerospace Engineering as well as an MS in Aerospace Engineering, both from Auburn University. He has four years experience in the areas of adaptive and composite materials. In addition, he has two years experience in numerical modeling and injury biomechanics.

B. Joseph McEntire, USAARL, P.O. Box 620577, Fort Rucker, AL 36362-0577; Telephone (334) 255-6885; Fax 255-7798; E-mail mcentire@rucker-emh2.army.mil. Mr. McEntire is a Mechanical Engineer working for the U.S. Army Aeromedical Research Laboratory in the Aircrew Protection Division. He holds a BS in mechanical engineering from Clemson University, and an MS in engineering from the Georgia Institute of Technology. He has over 15 years experience in the field of military protective equipment, injury biomechanics, and accident investigation through employment with private industry, the U.S. Navy, and the U.S. Army.

Nabih M. Alem, USAARL, P.O. Box 620577, Fort Rucker, AL 36362-0577; Telephone (334) 255-6892; Fax 255-7798; E-mail alem@rucker-emh2.army.mil. Dr. Alem is a Research Biomedical Engineer with U.S. Army Aeromedical Research Laboratory in Fort Rucker, Alabama. After obtaining his Ph.D. from the University of Michigan, Dr. Alem worked as a research scientist in the areas of transportation safety and biomechanics of impact. At the Aeromedical Research Lab, he is the primary investigator on several in-house research protocols, acts as a mentor to newcomers to human factors research, and provides continuity to the research programs at the Aircrew Protection Division. Dr. Alem has provided health hazard assessments of acceleration forces of mine blast and whole-body vibration effects to Army systems developers and program managers. The focus of his current research is the effects of head supported weight on female Army pilots during prolonged helicopter missions.